

## Gobbinsite and garronite assemblage produced by the intrusion and alteration of subvolcanic bodies (External Zone, Betic Cordillera)

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Phyllosilicate and zeolite minerals are a major constituent of hydrothermally altered mafic rocks and their host-rocks. Once volcanic and subvolcanic bodies are emplaced, the primary magmatic phases formed during cooling (i.e., olivine, anorthite-rich plagioclase, pyroxenes, oxides and glass) are metastable and can be replaced by secondary mineral phases such as clays, zeolites, carbonates and silica minerals. The intrusion of subvolcanic bodies during Jurassic in the Subbetic Zone of the Betic Cordillera generated hydrothermal systems that produced an intense alteration of the igneous host materials. We have carried out a mineralogical and petrographic study that revealed the formation of clay-mineral and zeolite assemblages during the evolution of the hydrothermal system. The samples were collected from a laccolith of dolerite from the Sierra de San Pedro (Jaén province, S Spain) whose igneous assemblages contain labradorite, albite, K-feldspar, diopside, olivine and biotite.

Zeolites were only found in slightly altered rocks. These samples are characterized by the presence of many cavities, whose abundance and size are variable in. These cavities are filled by zeolite minerals that appear as radial aggregates with massive growth of many fibrous bundles completely filling the cavity. Most of these aggregates are made of gobbinsite that occurs as colourless fibrous crystals that elongate on *c*. Optically, gobbinsite has parallel extinction and negative sign of optical elongation. Garronite can be observed in some BSE images, occurring as discrete fibers that form clusters of garronite-gobbinsite intergrowths within zeolite aggregates. Most of the biotite grains in these scarcely altered samples are fresh. BSE images of these biotite plates are homogeneous suggesting the absence of intergrowth with other minerals and EDX results are also very homogeneous. However several BSE images show chlorite lamellae up to 10  $\mu\text{m}$  thick within the biotite grains.

The existence of chlorite in biotite indicates the presence of a retrograde modification after the dolerite intrusion, which could be formed during an initial high-temperature stage of the hydrothermal process. Therefore, the presence of chlorite corresponds to hotter conditions of alteration than those of that produced the formation of zeolites. The zeolite mineralogy was probably controlled by the fluid composition. Gobbinsite ( $\text{Na}_5(\text{Al}_5\text{Si}_{11}\text{O}_{32})_z11\text{H}_2\text{O}$ ) and garronite ( $\text{NaCa}_{2.5}(\text{Al}_6\text{Si}_{10}\text{O}_{32})_z13\text{H}_2\text{O}$ ) belong to the natural gismondine-type zeolite group with four double-connected 4-ring building units (GIS group) consisting of (Si,Al) $\text{O}_4$ -tetrahedra. Natural gismondine-type zeolites are normally formed under hydrothermal postmagmatic conditions. Experimental studies have revealed that the formation of these zeolite phases was only dependent on the chemical composition of the glassy starting product. The main responsible for the growth of gobbinsite over the garronite crystals could be the relative increase of Na in the solution during the alteration process. Therefore, the dominance of Na among extraframework cations in the overgrown gobbinsite crystals is justified with later cation exchange with sea-water enriched fluids.